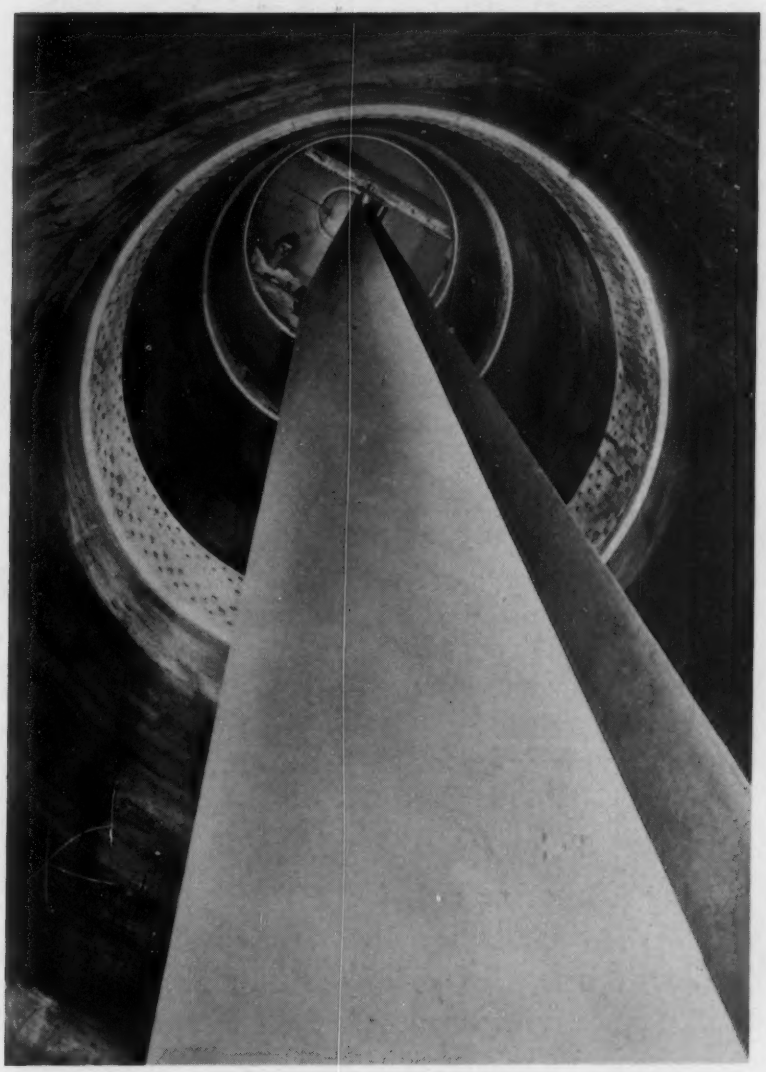
THE TECH ENGINEERING NEWS



HIGH-SPEED PHOTOGRAPHY

AEROLOGICAL OBSERVATIONS IN WEATHER FORECASTING

DECEMBER VOLUME XIV

A bird's-eye view showed the way

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THE TECH ENGINEERING NEWS

DECEMBER, 1933
VOLUME XIV
NUMBER 7

. . . CONTENTS . . .

COVER: *Looking up through the giant insulating column to the spherical terminal of the M.I.T. Round Hill high-voltage generator. The paper belt, which carries the electrical charges to the sphere, is in the foreground.*

FRONTISPIECE: THE CLEVELAND TERMINAL BUILDING

AEROLOGICAL OBSERVATIONS IN WEATHER FORECASTING 127
By Hurd C. Willett

ULTRA-HIGH-SPEED PHOTOGRAPHY 130
By Herbert E. Grier '33

THE TEN-MILLION-VOLT ELECTROSTATIC GENERATOR 132
By Vinton K. Ulrich '35

PROTECTION FOR THE MARINER 134
By Charles R. Mabie

EDITORIALS 136

ENGINEERING DIGEST 138

RESEARCH IN REVIEW 140

THE NEW MELLON INSTITUTE 144

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THE CLEVELAND TERMINAL
BUILDING AT NIGHT

THE TECH ENGINEERING NEWS

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VOLUME XIV | DECEMBER, 1933 | NUMBER 7

AEROLOGICAL OBSERVATIONS *in Weather Forecasting*

By HURD C. WILLETT
Professor of Meteorology
Massachusetts Institute of Technology

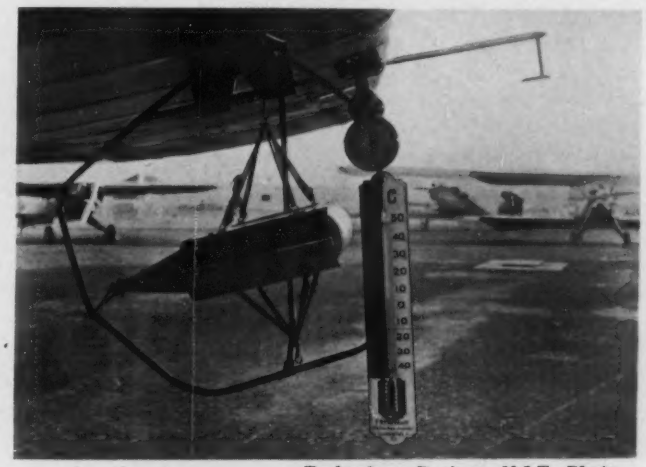
UP to about fifteen years ago short range weather forecasting in all the principal meteorological services was based essentially on a consideration of the distribution and changes in distribution of the atmospheric pressure at sea level. Isobars drawn on the synoptic weather map enclosed areas of high or low sea level atmospheric pressure. Isallobars (lines of equal pressure change) enclosed areas of rising and falling pressure. Experience showed that clear cool weather is usually associated with areas of high pressure, and warm damp weather with areas of low pressure. Rising temperature and falling precipitation were found to characterize regions of maximum pressure fall; and falling temperature and clearing skies, regions of maximum pressure rise. The whole problem of weather forecasting then reduced to the correct prediction of movements of highs and lows and areas of change in the pressure field. This prediction was made empirically by a combination of past experience and an extrapolation of the tendencies shown in the current series of maps. Very little effort was made to give any physical interpretation or explanation of the observed pressure changes or of the accompanying meteorological phenomena. Obviously, in weather forecasting of this type there was little need of, or place for, observations from the upper atmosphere.

During the World War, when international communications were so restricted that it was impossible to obtain observations for a complete weather map over northwestern Europe, the Norwegian meteorologists, under the leadership of J. Bjerknes, tried to compensate for this lack of observational material by the careful analysis of the observations of a comparatively dense network of stations over a relatively small area. Then for the first time was realized the frequency of occurrence and the meteorological significance of discontinuities in the fields of the meteorological elements in the atmosphere. These surfaces of discontinuity, or fronts, were found to exist between air currents of polar or tropical origin, possessing characteristic properties in the form of distinct differences in temperature, moisture content, and vertical stability. It was noted further that the important weather changes and general meteorological activity, that is, changes in wind direction and velocity, in temperature, and the occurrence of cloudiness and precipitation are associated with the passage of such atmospheric discontinuities. The typical active cyclone (low pressure area) was observed to consist of a large cold sector and a smaller warm sector, with sloping discontinuities between the warm and cold air such that the cold air lies in a wedge beneath the warm air. Precipitation, instead of occurring generally throughout the low, occurs in localized zones where the warm air is actively overrunning the cold air or being actively lifted by the cold air along these sloping discontinuity or front surfaces. A carefully analyzed weather map, on which the cold and warm currents (air masses) are definitely bounded and consequently the fronts accurately located, presents a physical interpretation of the processes taking place in the lower atmosphere, and therefore furnishes a physical rather than empirical basis on which to make weather forecasts.

Hence when modern methods of weather map analysis are used, the problem of weather forecasting resolves itself into two parts:

(a) The correct estimation of the displacement on the map, during the period of the forecast, of the air masses and fronts indicated, and

(b) The correct estimation of the type of weather to be associated with the prevalence of each air mass, and the sequence of weather changes to be associated



Technology Review—M.I.T. Photo

A portion of the apparatus used in obtaining meteorological data is suspended from the wing of the plane.

with each front passage at the point in question during the period of the forecast.

The first part of the problem remains much the same as it was when forecasting was based entirely on the movement of highs and lows and areas of maximum positive or negative change in the pressure field. But instead of studying the movement of rather indefinite formations in the pressure field, we are studying the displacements of clearly defined air masses and fronts. The definiteness of the structures which we are following on the maps, and the concentration of the important weather changes along relatively narrow frontal zones, makes possible a greater degree of precision in the details, especially the timing, of the weather forecasts. Changes in pressure distribution, instead of being regarded as the prime cause of weather changes, are regarded as one consequence among others of the physical processes in the atmosphere which are producing the weather and weather changes. Nevertheless, the close observation of the tendencies in the pressure field still frequently gives us the best indication of the development to be expected in a given situation.

But it is in the second part of the forecast problem, that of estimating the weather sequence to be expected with the sequence of air mass and front passages over a given station, that the modern analytical methods of forecasting have the greatest advantage over the older methods. The distribution of the meteorological elements in a high or low is extremely indefinite and uncertain, varying greatly from one instance to another, depending upon the distribution of air masses and fronts in the given area, and the nature of the interaction taking place between the air masses at the fronts. Furthermore rapid changes in the structure, and consequently in the distribution of temperature, precipitation, and winds about the center, may take place in a very short time. Irregularities and peculiarities in the structure and development of individual disturbances can be forecast only on the basis of a correct and complete analysis of the current situation. But such an analysis, to be complete, must represent the atmospheric structure not only at the ground, but up to considerable elevations. Obviously for this purpose considerable observational material from upper levels in the atmosphere is necessary. By the widespread acquisition and utilization of such material our present analytical methods might be improved almost indefinitely. Hardly a beginning has as yet been made on the possible development of weather forecasting in this direction.

We have seen that our weather is controlled either by the type of air mass present, or near the boundary between two air masses, by the interaction taking place along the front between them. Consequently, in order to make a weather forecast based on the passage of a succession of such air masses and fronts, we need in addition to surface weather observations, upper air observations for the following two general purposes: (1) To determine air mass properties, and (2) To determine the structure of fronts.

Air Mass Properties

Experience has shown that the air masses (large scale air flows) occurring in any given region can be classified into a few simple types, having quite definite properties, depending upon the source of the air mass and the path which it has followed. Obviously the careful study of the properties of these air mass types must be of great assistance in forecasting the weather which will occur with the passage of the air mass. This applies not only to the surface conditions of temperature, moisture, but even more to the vertical distribution of these elements. Upon the vertical distribution of temperature and moisture in the air mass depend the following important weather phenomena within the mass:

(a) Structure of winds, whether stratified and smooth in flow, or convectively turbulent and gusty.

(b) The presence or absence of cloud forms, and if present whether of the low stratified type, with poor visibility and fog, or of the higher convective type, with good surface visibility.

(c) The presence or absence of precipitation, and if present whether of the mist and drizzle type, or of the convective shower or snow flurry type.

(d) The degree of horizontal visibility, whether cut down by the accumulation of dust, smoke, and fog near the ground, or improved by the rapid vertical transport and dispersion of these obscuring elements throughout the atmosphere.

It is possible indirectly from the observation of the horizontal visibility and the precipitation and cloud forms to draw conclusions as to the properties of the air mass, instead of determining them by direct aerological soundings. This is known as indirect aerology. But experience has shown this method to be comparatively unreliable. The information obtained is only qualitative, not quantitative, so that much less accurate estimates can be made of possible developments within the air mass, and in the absence of cloud forms there is very little information to be obtained by this indirect method.

The only general investigation of air mass properties which has been made in North America is the one which was recently completed by the Meteorology Department at the Massachusetts Institute of Technology. Several investigations of this type have been made in Europe, but every large region for which analytical weather forecast methods are to be used must be studied individually, for the characteristic air mass types are not the same in different parts of the world. For this investigation of the North American air mass properties, the Technology aerological station was a key station. Reports from the Weather Bureau aerological stations and from a few Army and Navy stations in different parts of the country were also used, but our station was the only one furnishing and making such observations in the northeastern part of the country, where the typical air masses were found to show very distinctive and interesting properties aloft. One interesting and surprising fact found here is that although the continental Polar air mass from the northwest (typical cold wave air mass) is much warmer at the surface than in the northwestern United States, at high levels, above 3 kilometers, it is found to be much colder than in the northwest. This means that this type of air mass in New England is a comparatively unstable and convectively turbulent mass.

In addition to the fact that the Institute aerological station is the only such station located in the northeastern states, it also was the most regularly operating station, the one furnishing most reliable observations, and the one reaching highest elevations, of all the stations whose reports were available for this investigation.

Structure of Fronts

Further study of atmospheric discontinuities, especially of the frontal type between air masses, is

probably at present the most needed type of investigation for the further development of the analytical method of weather forecasting. Our theories as to just what occurs at these frontal surfaces of different types are still very sketchy and to a considerable degree hypothetical. The formation of clouds and precipitation at frontal surfaces accounts for much the greater part of our unsettled weather. This is especially true of the extensive areas of cloudiness and falling precipitation which accompany the general widespread storms that occur at all times of the year, and most frequently during the cold season. All of this widespread frontal condensation of moisture in the atmosphere is dependent upon the vertical displacement upwards of the warmer air masses by the colder. Consequently it becomes essential, if intelligent weather forecasts are to be made, to be able to understand the mechanics of this frontal activity well enough to anticipate both the amount of the vertical displacement of the warm air mass which will occur in a given situation, and the amount of condensation to which this lifting will lead. At the same time, descending movement in the cold air masses leads to a heating and lowering of the relative humidity in this air, and consequently to a dissipation of clouds already formed.

The amount of lifting of the warm air current must obviously depend upon the relative movement of the warm air mass against the sloping discontinuity which marks the edge of the denser cold air mass, and upon the slope of that discontinuity surface. The amount of condensation which will follow from a given lifting of the warm air mass will depend upon the vertical temperature and moisture distribution in the warm air mass, or in other words, upon the same air mass properties the determination of which we have considered above. From this simple illustration it can readily be imagined what complexity may be found in the relative movements and the vertical displacements of warm and cold air masses along frontal discontinuities, and the practical difficulties which may be met in the attempted analysis of the more complex situations. But it is easily seen what importance is to be attached to a better understanding of the structure of frontal discontinuities, that is, to a knowledge of frontal slopes, of the sharpness of the discontinuity at upper levels, and to the relative movement of the warm and cold air masses at all levels. The continuance or breakdown of dynamic equilibrium at the front depends upon these factors, and consequently the whole trend of the development in a given situation.

Information of this kind which will lead to a better understandng of frontal structure can be obtained only through numerous aerological soundings taken in series at times of front passage. Since the zone of frontal activity is frequently rather narrow, special planning of aerological flights is necessary to get good information on frontal structure. Usually, because of bad flying conditions, aerological flights are avoided at just the time they are most needed, close to the front itself. The Technology aerological station is the only station in North America where any attempt has been made to get series flights during the passage of fronts. The numerous series flights made on days of front passage in Boston furnish the only observational material available in this country which has been gathered with special consideration of its applicability to the important and difficult problem of determining frontal structure. And there is no other place in this country where investigations of this type are being pursued, although in Europe considerable progress has been made along these lines. But as in the case of the study of air mass properties, the peculiarities of frontal structure must be investigated independently in each region where analytical methods of weather forecasting are applied. At the present time two men in the Meteorology Department are engaged in working up the Institute aerological material, supplemented where possible by other aerological ascents, in the investigation of the structure of various front types in the eastern United States. Cross sections are being prepared in a number of cases showing the vertical distribution of the meteorological elements in and on either side of the front surface. In this way it is hoped to reach a better understanding of many of the unexpected developments which occur frequently during the passage of fronts, and which at present render all weather forecasts to some degree uncertain. Even the solution of the general problem of the sources and liberation of energy responsible for the intensification of storms, and the exhaustion of the energy sources and the dissipation of storms, must be attacked through the extension of these same analytical methods to include the upper levels of the atmosphere. This requires more numerous aerological soundings (sounding balloons) extending into the stratosphere.

In addition to their special utilization in these long range meteorological research projects, the Massachusetts Institute of Technology aerological soundings are used along with the Weather Bureau and the Army and Navy observations of the same type, in connection with the daily analysis and interpretive discussion of the

(*Continued on page 142*)

Technology Review.

A view of the instrument panel of Technology's meteorological plane, showing the host of instruments employed. The radio equipment is located on the lower portion of the panel.

ULTRA - HIGH - SPEED PHOTOGRAPHY

By HERBERT E. GRIER '33

MOTION PICTURES are one of the most useful agencies for entertainment, education, and research; and each year many new uses are found. One particularly interesting and useful branch of motion picture photography is that of high speed motion pictures—the taking of pictures at a rate greater than the speed of projection. For instance, there are a host of things in this world too fast for the unaided human eye to see—a bee in flight is merely a moving blur; the breaking of a soap bubble appears to be an instantaneous event—and to see what is really occurring, the speed of the event must be reduced. In the engineering field there are high-speed machines with their vibrating springs, cams, gears, and other machine parts. The unaided eye tells very little as to why they do or do not operate properly, but if they can be made to perform slowly, through the medium of the high-speed camera, much valuable information can be gained.

In this sense the high-speed camera is to the mechanical engineer what the oscillograph is to the electrical engineer. It enables him to see the rapid complicated motion of his machines and to measure speeds, accelerations, deformations, and many other important quantities. With the permanent record that the camera affords he can see the event as many times as he wishes and is able to measure and plot the relative motions of the parts.

Technology Review

A stream of water remains motionless. This remarkable photograph was made possible by high-speed photographic apparatus designed at the Institute.

High-speed motion-picture photography embraces a wide range of picture-taking speeds, but the most useful for machine analysis appears to be from one to two thousand pictures a second. The highest practical operating speed of an intermittent motion mechanism is not greater than one to two hundred frames a second. The mechanical difficulties of starting and stopping the film for each exposure at speeds greater than this are practically insurmountable because of the limitations imposed by the mechanism and by existing materials. All high-speed cameras which operate at speeds much greater than about two hundred pictures per second utilize continuously moving film which does not stop for each exposure. There are two types of cameras with continuously moving film: (1) Those cameras which use a moving optical system which effectively stops the image on the film for the duration of the exposure and, (2) Those cameras which use intermittent illumination of sufficiently short exposure to accomplish the same purpose. The first type has the advantage that it can be operated in the open such as in the sunlight, and can photograph incandescent objects. The second type has the advantage of taking pictures in a sufficiently short time to stop effectively the motion of a rapidly moving object.

The pioneer in the development of the first type of camera just mentioned was C. F. Jenkins. The theory upon which his machines are based is as follows. If the film is moved at a certain speed and the image is caused to move at the same speed, each will be stationary with respect to each other, and the image will be sharply impressed upon the sensitive emulsion. In his first machines Jenkins interposed a rotating prism between the lens and the film to accomplish this purpose.

This type of mechanism later was abandoned but Jenkins retained its fundamental principles; his practical camera "The Chronoteine Camera" employed a moving lens to cause the movement of the image. It is obvious that if the lens moves in the same direction and with the same speed as the film, the image and the film will be stationary with respect to each other. A metal lens wheel thirteen inches in diameter is fitted with forty-eight matched lenses and is rotated in front of the moving film, successive lenses exposing successive pictures. This wheel is geared to the drive sprockets so that the image is at all times stationary with respect to the film regardless of the speed of the camera. The highest speed possible with this camera is thirty-two hundred pictures a second, and at this speed a four horsepower motor is required to drive it. Since the film velocity is two hundred feet per second, the use of a friction guide would cause the film to catch fire. In practice the film is led through a flat tube, being held in the center, away from the sides, by the layer of air that adheres to a celluloid film travelling at this velocity.

A very interesting camera of this same type was designed by Heape and Grylls for the British Admiralty. This camera is arranged for stereoscopic work. Two strips of film are wound side by side upon a steel drum sixty-seven inches in diameter, and each strip of film has its own lens wheel carrying forty matched lenses. The drum is rotated at one thousand revolutions per minute, the film being held on by vacuum; and at this speed pictures are taken at the rate of five thousand a second. This camera gives excellent results although it has the following disadvantages:—it weighs four tons complete with a ten horse-power driving motor, and intense illumination

Professor Edgerton's high-speed camera capable of taking several thousand pictures a second. The motor at the right drives the main sprocket in the center of the camera. A commutator for timing the flash is fastened to this sprocket in order to obtain perfect synchronism. The series motor used on lower take-up reel is on the other side of the camera.

is required to take a picture. To illuminate a field fifteen inches in diameter requires two one hundred and thirty ampere arc lights. This camera was designed to observe the action of large shells penetrating armor plate and has remote control.

Some very excellent pictures have been obtained by Dr. Suhara at Tokyo University. Dr. Suhara uses a drum camera and a rotating mirror; the principle is exactly the same as that used in Jenkins' and in Heape and Grylls' cameras. The drum is fifty-five inches in diameter, the film being placed upon the inner periphery so that the centrifugal force will hold it in place rather than tend to throw it off. The drum is driven at twenty-five hundred revolutions per minute, and the camera takes one thousand consecutive pictures four millimeters high at a rate greater than forty-one thousand a second. In his description of this camera, Dr. Suhara mentions that he is developing a similar type to reach speeds of sixty thousand a second. This camera, in common with the Heape and Grylls camera, has the disadvantage of weight and requires high light intensity.

The Eastman Kodak Company and the Electrical Research Products, Inc. have recently made available a camera capable of a speed of two thousand pictures a second. This camera employs a continuously moving sixteen millimeter film and a rotating rectangular prism, two sides of which are blanked out so that they act as a shutter. In its present form this camera is combined with a tuning fork clock which affords an accurate and convenient method of measuring elapsed time. A picture of the clock is photographed on the edge of film beside the photograph of the subject which is under observation.

The second line of development previously referred to was the use of intermittent light of short duration. The requirements for such a light source are: high intensity, high actinic value, and an extremely short duration of flash. An electric spark obtained by discharging a condenser answers all these requirements and is the light source most commonly used in this branch of photography. The film is moved continuously, each flash of light being so short that the film does not move perceptibly during the flash. In this way sharp images are impressed upon the film each time the light flashes. The great advantage of this type of camera over the ones employing constant illumination is that the time of exposure is much less, being of the order of one micro-second, which effectively stops the motion of even the fastest rifle bullets.

When Lucien Bull of the Marey Institute abandoned the intermittent motion, he turned to discontinuous light as the solution of the problem. His camera was a drum ten and three-tenths inches in diameter revolving at six thousand revolutions per minute in a vacuum, employing as a light source a one millimeter spark gap between hemispherical electrodes, placed in the focus of a concave mirror. With this apparatus Bull was able to attain a speed of twenty thousand pictures a second, the pictures being five millimeters high. The number of consecutive pictures taken is limited by the circumference of the drum as only one turn of the drum can be utilized. A mechanical shutter opens and closes after one revolution.

Dr. C. Cranz of the Berlin Military Academy obtained a large number of pictures of high-speed bullets and the action of modern automatic pistols. His apparatus was very similar to Bull's differing only in such small details as the diameter of the drum.

The illumination provided by a spark in air is ample to take shadow photographs, that is, silhouettes, but it is not sufficient to take pictures by reflected light. It was found that if a condenser was discharged between points in mercury vapor an extremely intense light was produced; this principle was first used in practice by C. T. R. Wilson for taking single instantaneous pictures.

Professor Edgerton of the Electrical Engineering Department at the Institute, has greatly improved an intense stroboscopic light source utilizing a condenser discharge in mercury vapor and with it has been able to increase greatly the practicability and usefulness of this second type of camera. One of the most important properties of this new flashing circuit is the ease of control. The previous cameras had commutators to synchronize the flashes to correspond to the speed of the film, and these were required to carry the entire power which went into the spark. For this reason the power was made as low as possible because of difficulty with the sparking at the commutator. Furthermore, arcing at the segments tends towards unequal wear which causes unevenness in the spacing of the pictures. By the use of thyratron pulse amplifiers which have been developed here at the Institute, the commutator is now required to carry only a small fraction of an ampere. As many lamps as desired may be flashed in parallel, which make it pos-

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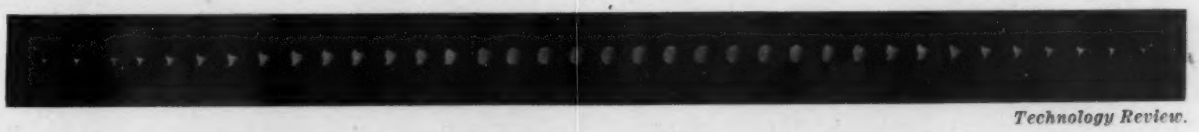


Technology Review.

A high-speed photograph of the opening and closing of a camera shutter taken at a speed of 4200 pictures per second with Professor Edgerton's camera.

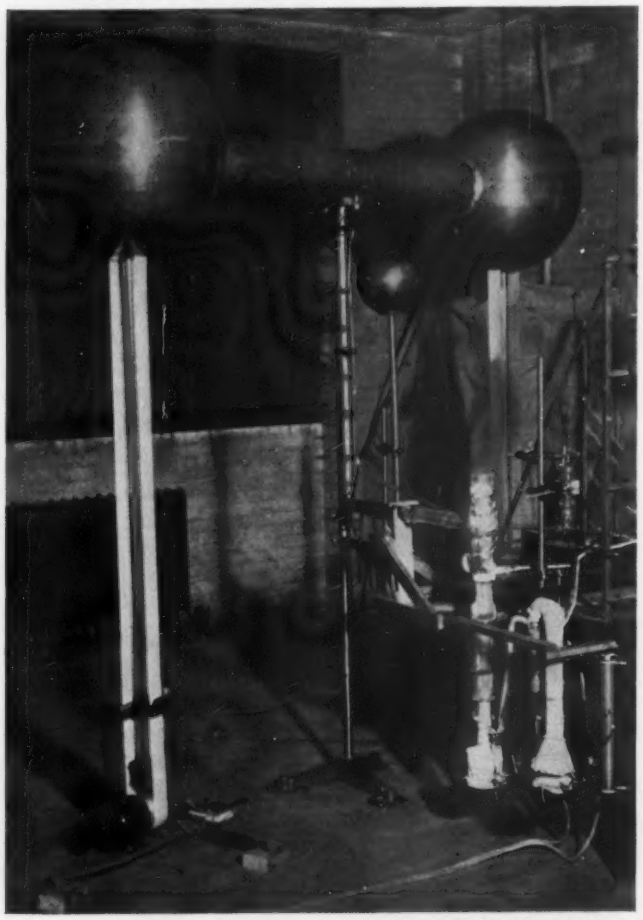
THE TEN - MILLION - VOLT ELECTROSTATIC GENERATOR

By VINTON KENNETH ULRICH '35

A REMARKABLE characteristic of many, if not most of the remarkable achievements of the human mind is the remarkable fact that, complicated and abstruse as they appear, they are fundamentally simple—once they have been done. The Van de Graaff generator, which is now so much in the news, offers good illustration of this paradox.

Some twenty-five centuries ago the Greek Thales discovered that by rubbing amber, he could make the amber do strange things. We know that what Thales did was to isolate a number of electrical charges, producing a potential of small magnitude. His method of recharging the rod, after the first charge had been dissipated, was to rub it again. From a practical point of view his discovery meant very little.

Some twenty-four centuries later, however, Faraday took a leaf from Thales' book and performed his "ice-pail" experiment. Thus he discovered that an object gave up all its charge when brought in contact with the inner wall of a pail, regardless of the amount of charge which might already have been on the pail. Repetition of the operation permitted him to get an host of charges segregated on the pail, which was supported by an insulator.



Technology Review.

An early model of the Van de Graaff generator designed to produce 1,500,000 volts. The belt for charging the sphere and the driving motor are clearly shown. The cylinder suspended between the two two-foot spheres is a vacuum tube of special design.

Some five years ago, the ideas of Thales and Faraday were catalyzed by the desire of the present-day physicists to explore the atom. In order to do so, they had to have extremely high voltages at their command. Seeking a source thereof, Dr. Robert J. Van de Graaff, then a Rhodes scholar at Oxford, returned to the ideas behind one of the so-called Classical experiments in elementary electricity—the charging of a Leyden jar condenser to obtain a potential. This experiment was but the outgrowth of what Thales had long before discovered. Thus evolved the Van de Graaff electrostatic generator.

The construction of the generator represents a gigantic engineering accomplishment, yet it is the height of simplicity in both design and principle. The machine, because of the size contemplated, had to be simple in construction to avoid mechanical difficulties and a prohibitive cost.

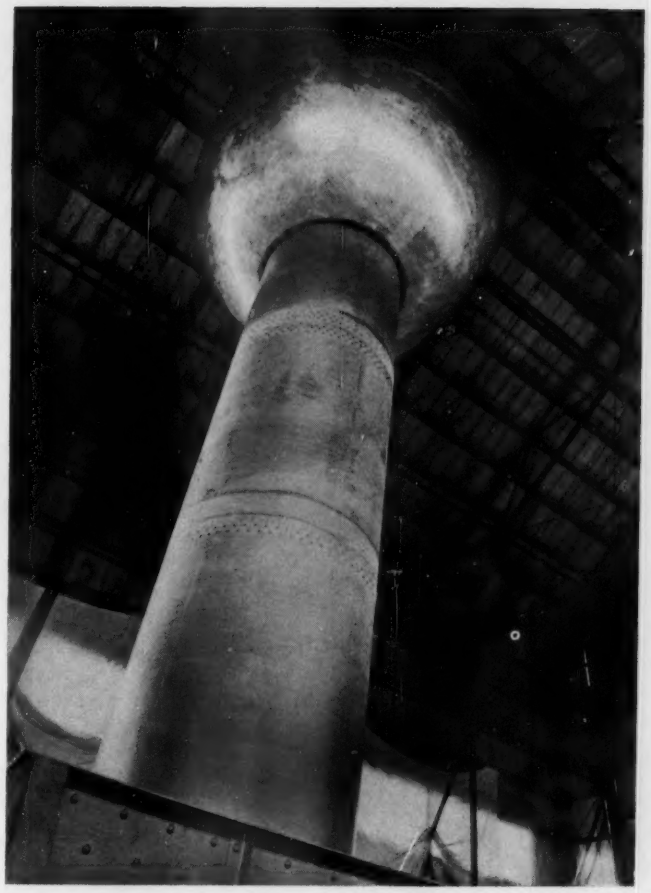
Since, any high voltage requires well insulated terminals, the most logical form was found to be a large sphere mounted on an upright column of insulating material. These terminals serve merely as reservoirs for storing the electrical charges. In order to maintain a constant charge on the spheres, thereby making the system a generator, it was necessary to bring up the charges from the grounded base of the unit.

Development of the design to this stage suggested that for constant charging, some form of carrier which would continually return to the ground to bring up more charges of electricity would be required. An endless belt of an insulating material which, while holding a charge, would not permit it to run back, was devised, and by this means the electrical charges are stored in the terminal spheres.

In one of the first generators, constructed to test the practicability of the theory involved, a sphere about two feet in diameter was supported by a long glass column. An accompanying picture clearly shows the constructional details of that machine. A small motor at the base is used to run the belt at a high speed. As a portion of the belt travels up it carries a multitude of charges to the sphere and deposits them there.

In order to make the belt perform double duty, charges of the opposite polarity from those carried up are carried down to the base. In this way the sphere is charged twice as rapidly, for the removal of charges of undesired polarity contributes to building up the voltage, as does the addition of the desired charge. Also, the presence of these charges at the base self-excites the generator by pulling charges of the desired polarity from the ground.

The process is not unlike the old-fashioned method of raising water from a well by means of small buckets on an endless chain, each dumping its load as it turns over a pulley at the top. In the generator the electri-



Technology Review

Looking up at the fifteen-foot polished aluminum sphere.

cal charges are taken off by a "collector" fastened near the upper pulley.

It should be noted that while one machine is storing up negative charges of electricity, the other is storing up positive electricity. When the store of electricity in each machine has reached a potential of five-million volts, for which each unit was designed, the terminals have a combined electrical pressure of ten million volts.

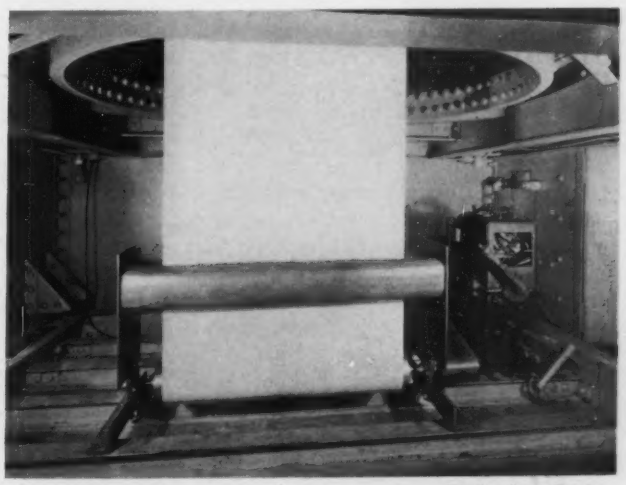
The ten-million-volt generator consists of two separate units, each with a fifteen-foot spherical terminal weighing three-thousand pounds, which rests upon a hollow cylindrical column twenty-five feet high and six feet in diameter. The columns are mounted on heavy four-wheeled trucks operating on a railway track fourteen feet wide. This arrangement permits variation of the distance between the two terminals and also makes it possible to move them out into the open to avoid twenty-foot flashes to the roof girders of the airship dock in which the generator is housed. Since these flashes occur at a potential of about seven million volts, it has not been possible to obtain the ten million volts for which the generator was designed. But when the generator is operated in the open, as planned, this limitation will no longer exist.

The construction of the huge spherical terminals presented new problems, for there was no precedent after which they could be designed. It was necessary that the spheres be fifteen feet in diameter and have a very smooth surface in order to reduce corona discharge. The material used in the construction had to be of minimum weight, yet have sufficient strength to obviate internal bracing, for any obstruction would hinder the work of those inside. The globes were fabricated in orange-peel sections, there being six sections to each hemisphere. The sections, made of one-fourth inch aluminum alloy, were first pressed into shape and then joined at the equator and along the sides by means of butt welds. The welds were later ground smooth, and the entire surface was polished and waxed. As a testimony to the expert workmanship, it can be stated that the welds are so nearly perfect that they cannot be seen at a distance of several feet, and that the completed shell is spherical within considerably better than one per cent. Each sphere weighs three thousand pounds and is amply strong without internal bracing except where the supporting column is attached.

The supporting columns, six feet in diameter and over twenty feet in length, are made of a highly insulating material known as textolite. This material is manufactured by rolling paper onto a large mandrel and binding the layers together with shellac under high pressure and temperature. The resulting column has the necessary mechanical strength to support the spheres and to resist the wind forces which may exceed several thousand pounds when the generator is operated in the open. Even though the force of attraction at full voltage exceeds five hundred pounds, there is no vibration perceptible to those in the sphere when a flash jumps from one sphere to another. Since textolite was not manufactured in cylinders of sufficient length, it was necessary to construct the column in three pieces. A unique method of joining the three cylinders was employed. A smaller diameter of tubing is used as a cover plate, and the sections of the column are "riveted" to this. Since the purpose for which the generator was built precluded the use of ordinary metallic rivets, textolite dowels dipped in shellac were forced into the holes. About a thousand were used in joining the three lengths which formed each column. The photograph on the cover of this issue quite clearly shows one of these joints with its many rivets arranged in staggered rows.

Like the sphere, the column had to be large in diameter and smooth to prevent the losses in power which occur with a corona discharge. Its length is

(Continued on page 143)



Technology Review

The driving power for the generator is located in the base of the machine. To the right of the paper belt is the motor and its starting duty.

PROTECTION FOR THE MARINER

By CHARLES R. MABIE
Instructor, Massachusetts Institute of Technology

Illustrated by the author

IT has been recently stated by a Government official that the general public knows less about the work of the lighthouse board than about any other form of public works. The lighthouse board has charge of the construction and maintenance of all lighthouses, lightships, fog signals, buoys, minor lights, and day beacons. Since this field is too large for adequate treatment in an article of this length, the present writing will be confined to lightships and buoys.

Lightships are used where it would be impracticable to build lighthouses, such as on shifting shoals and submerged ledges. They are also used to mark dangers at sea and the approaches and entrances to harbors. In many instances they mark important points in the courses of vessels and are used by mariners to check their courses. The first lightship on our coast was placed in service on the Elizabeth River, Chesapeake Bay, in 1820. Three years later the first outside ship was moored off Sandy Hook. From then on there was built, on an average, about one a year until 1852, when there were 38 ships, 28 of which were in bays and sounds. These early ships had no motive power other than sail, and so inadequate was their equipment that they were often blown from their courses and badly damaged. They were build of wood, but as time went by, more iron and steel were worked into their construction, until today the modern lightship is an all-steel vessel. They are self-propelled, have water-tight compartments, and are up-to-date in all their appointments. A great deal of attention has been given to their design relative to their stability, to increase both the efficiency of the light and the comfort of the men. The main mooring chain consists of wrought iron links $1\frac{5}{8}$" in diameter with cast iron studs. Mushroom anchors of a special design are used to moor her to the bottom. In the most exposed positions, a spherical buoy is attached to the chain to help carry its weight, thus easing the strain on the vessel in rough weather.

The lighted beacons on the early lightships were ordinary ships' lanterns. Later, oil lamps with reflectors were hung around the mast, protected by glass cages. These lamps were lowered by day into houses with hinged roofs. Modern ships are equipped with steel masts with a gallery around the light. Some lightships have two masts while others have one. Some two-masted vessels show two lights at a time, and others show only one, keeping the other in reserve. The illuminant is acetylene, oil gas, or electricity. The lights are white or red, sometimes used in combination on two-masted ships. Both flashing and steady lights are employed.

Since the usual life of a lightship is about thirty years, it is necessary to build one or two new ones each year in order to maintain the present number of vessels on their stations.

Lightships are usually named after the shoal or ledge where they are anchored, and these names are quite appropriate. *The Hen and Chickens,* for instance, is made up of a mother shoal and a whole flock of little shoals. *Hedge Fence,* or *Fence,* as it is generally called, together with *Great Round,* describe the shape of their grounds, while *Cross Rip* is stationed where two currents come together at an angle, much as the *Cultivator* on George's Banks. *Stone Horse* and *Handkerchief* are also suggestive. It has been said that *Handkerchief* got its name from the fact that passengers on vessels passing by always waved their handkerchiefs. This is a very pretty, but doubtful, explanation of its origin.

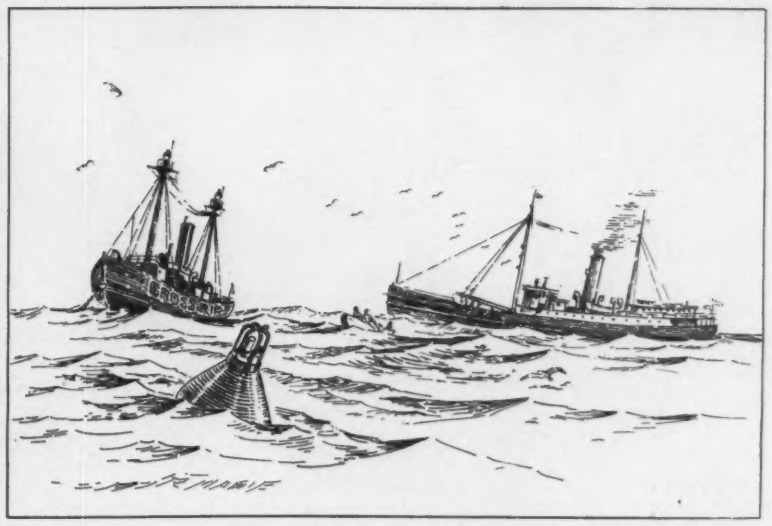
The water on these shoals is of varying depths. At mean low water, soundings at *Hen and Chickens* show from three to nine fathoms, a fathom being six feet; on *Hedge Fence,* one to four; on *Handkerchief,* one to six; and at *Stone Horse,* around a single fathom. Since the draft of the ships is greater than these depths, it becomes necessary to anchor them in the deeper water of a near-by channel. Since shallow water is very rough in stormy weather, a lightship crew must be able to stand a lot of tossing about. But even with sturdy ships, some suffer from seasickness, and are always exposed to the more serious danger of being washed overboard.

The most noted, and perhaps the most interesting lightship of the Massachusetts group is that at Nantucket, stationed about 42 miles southeast of Nantucket Island, thus occupying the farthest position from land of any lightship in the world. She is anchored in thirty fathoms of water on the southern edge of the Nantucket Shoals, one of the most dreaded areas of the Atlantic coast. This location is almost in a direct line of European shipping, and consequently in foggy weather the lightship is constantly in danger of collision. According to her captain, one liner came within three feet of her side.

Recently a new vessel has been put on this station, the old one being placed on "relief", that is, held in reserve to take the place of some ship that has to come off duty for cleaning or repair. The new boat has all the latest improvements, including Diesel-electric engines and a radio beacon. This last invention is proving a great aid to navigators. The mere fact that the old type of fog signal is only 2% as efficient as the radio beacon shows what a great improvement it really is. The old signals could be heard from five to ten miles, whereas a first-class radio beacon can be depended on up to 300 miles. The Nantucket station was first marked by a lightship in 1858. This boat broke her moorings and drifted onto Montauk point. Within a year another ship was sent to Nantucket where she remained for thirty-seven years. Several times she broke her chains and went adrift and, once it took her two weeks to regain her

position. However, the former Nantucket ship was salvaged, repaired, and placed back in service. In 1922, as lightship No. 11, she was still doing duty off New York.

One of the rare occasions of a lightship foundering occurred at this station. In 1905, during a severe storm, a relief vessel, anchored on the location sprung a leak. With all hands at the pumps, the water in the hold increased so rapidly that it was evident that she would sink unless help came speedily. The tender *Azalea,* notified by radio, set out from New Bedford and, in spite of the storm, reached the sinking ship. After several hours of desperate work, she succeeded in getting a hawser across and started for New Bedford with the ship in tow. But the damaged vessel never reached port; she sank ten minutes after the crew had been taken off. This is said to be the first rescue on the Atlantic coast effected by radio.



A sketch of a tender bringing provisions to one of the many lightships maintained by the government.

Buoys are fast gaining in popularity as an aid to navigation. They are similar to lightships, in that they mark shoals and other obstructions. They also indicate the approaches and entrances to harbors, fairways in channels, anchorages, and quarantines.

Buoys are painted a characteristic color and often given numbers to show the position of a channel or dangerous rocks. When coming into a harbor, red buoys with even numbers should be passed on the right hand, black buoys with odd numbers on the left. Buoys with horizontal red and black stripes mark some obstruction and can be passed on either side. Buoys with black and white vertical stripes indicate mid-channel and can be passed close to. Lightship stations are marked by buoys close by, with LV and the initial letter of their name on their side. The same scheme for marking buoys is generally followed by all maritime nations.

There are several types of buoys, falling into two classes: lighted and unlighted. The simplest form of unlighted buoys is the spar, both wooden and iron. The wooden ones are made of cedar, spruce, or juniper. The logs are peeled, tapered, and bound with iron bands. Can, nun, whistling, and bell buoys also belong to this class. Can buoys are cylindrical in shape while the nun tapers toward the top; both have watertight compartments to prevent them from sinking in case of collision. Whistling buoys are constructed of iron plates, in shape similar to a pear, with its smaller end uppermost. A tube extends through the buoy and about fifteen feet below. The upper end is closed by a headplate on which is mounted a whistle and check-valve while the lower end of the tube is left open. When the buoy rises on the wave, air is drawn into the tube through the valve, and as the buoy sinks, the pressure of the rising water in the tube forces the air out through the whistle. Bell buoys are built with a semicircular hull, on which is mounted an open superstructure containing a bell. As the buoy rolls on the waves, the bell is struck by clappers hung on the outside. Although bell and whistling buoys are quite sensitive and respond readily to the action of the waves, they may be quite inaudible in calm weather; hence they are placed where there is a ground swell, such as at the entrance to harbors or on a shoal.

Lighted buoys are a comparatively recent invention, the first gas buoy appearing in 1881. Electric buoys, supplied with current from the shore through cables, have been tried, but so much trouble was caused by the breakage of the cable that they have been discontinued. All the lighted buoys in the service now burn either compressed acetylene or compressed oil gas. Most of these are both flashing and automatic. The pressure of the gas in the reservoir operates the mechanism which admits, at set intervals, a sufficient amount of gas to the main burner. A pilot light ignites the gas, thus producing the flash. The gas used in the buoy is stored in cylinders containing acetone, which will absorb acetylene up to ten times its own weight. Free acetylene under 25 pound pressure is very explosive, so the tanks are completely filled with a porous substance to prevent the presence of any free compressed acetylene. One charging of gas will generally last a year. Some buoys in addition to their lights are provided with a bell or whistle. Such buoys are classed as combination buoys and sometimes have superseded lightships.

Buoys are not as dependable as light houses or lightships, for at times they go adrift. Once a lighted buoy was sighted by a sea captain a thousand miles from shore. Also they may be struck by vessels, especially in a fog. When this happens to a lighted buoy there is apt to be an explosion. This generally blows out the lens, which by far is the most expensive part of the buoy, some of them costing as much as four or five hundred dollars.

The establishment of numerous lightship stations, buoy positions, and isolated lighthouses, calls for the maintenance of a fleet of vessels to attend to their upkeep. These are called lighthouse tenders. Through the kind offices of the district superintendent at Boston, the author was privileged to make an observation trip aboard one of these. The vessel chosen for the trip was the *Anemone,* whose base is at Wood's Hole, and which operates on the Nantucket district. The *Anemone* is a vessel of about a thousand tons and carries seven officers and a crew of twenty-six men, mostly Portugese, from the Cape Verde Islands. I was informed that they made very good sailors and when once signed on, served long terms with the ship.

One of the largest tenders in the service is the *Cedar.* She is more than two hundred feet over-all, and of nearly 1800 tons displacement. She was built in 1917 and operates on the Pacific coast in the sixteenth district. The smallest one is the *Poinsettia,* a gasolene-

(*Continued on page 142*)

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EDITORIALS

PERMANENT RECOGNITION FOR THE GREEK IDEAL

ANY sort of college publication has three ways of paying its expenses. These are by subscription, by advertising, and by a subsidy from the college. Since the Institute does not make a practice of subsidizing undergraduate publications, it is necessary that the managing board make expenses through its subscriptions and its advertising.

With the natural falling off in revenue from the above two sources, it has become increasingly difficult for the *Technique* to earn enough to cover the cost of publication. Inasmuch as the year book offers recognition to the various organizations at Tech, it seems only right that these organizations help meet the expense of printing by paying for their space in the annual. This policy has always been followed by *Technique* and will be continued this year. There is, however, one exception, namely, the Athletic Association. For a very nominal sum, much less than is paid by fraternities and other organizations for a two page representation, the A.A. has been getting approximately thirty to thirty-five pages in the book.

Although the money turned over to the A.A. by the Institute should, in the main, be used for athletic events and equipment, it is also important that permanent recognition be given to those who have competed throughout the year on athletic teams representing the Institute. Moreover, in view of the fact that the A.A. is in a position to stand the expense of its place in the yearbook and since the *Technique* will certainly operate at a loss if the A.A. does not do so, it appears to be only logical that the A.A. cooperate in paying its share. There is no reason why the publications and other activities at M.I.T. should subsidize the A.A. through the indirect medium of paying its share of the publication cost of the *Technique*.

The only alternative is to decrease the size of the athletic section of the year book. To do so would decrease the value of the book to the students and would certainly detract from the impression which outsiders obtain from a perusal of the *Technique*.

It is to be hoped that the A.A. will view the situation from the standpoint of the publication of an inadequate and crowded athletic section in the year book of a school which is so often criticized because of its lack of emphasis on athletics.

RECOGNITION OF RUSSIA

THE recent announcement by the administration at Washington of the formal recognition of Russia is of far-reaching significance. It is generally evident that in this question of recognition of Russia, just as

in dozens of other major issues, the American attitude has undergone a complete reversal. Perhaps it has been the distressing economic conditions of the past few years, that dark period which has changed so many of our previous concepts, which has contributed to this reversal of opinion. Until now, America objected to Russia's system of government, which she considered contrary to her ideals. Recently America has had an opportunity to see the evils of her own system of capitalism, and she is accordingly more sympathetic.

Disregarding the question of recognition from a moral standpoint, the arguments for which are rather weak, the news of recognition is of especial interest to the engineer and the technician. There is no doubt that Russia is today, as America was in the nineteenth century, the land of opportunity. Ridiculed the world over for its five year plan, the Soviet government nevertheless is carrying out tremendous industrial programs in which there is an urgent need for trained technical men.

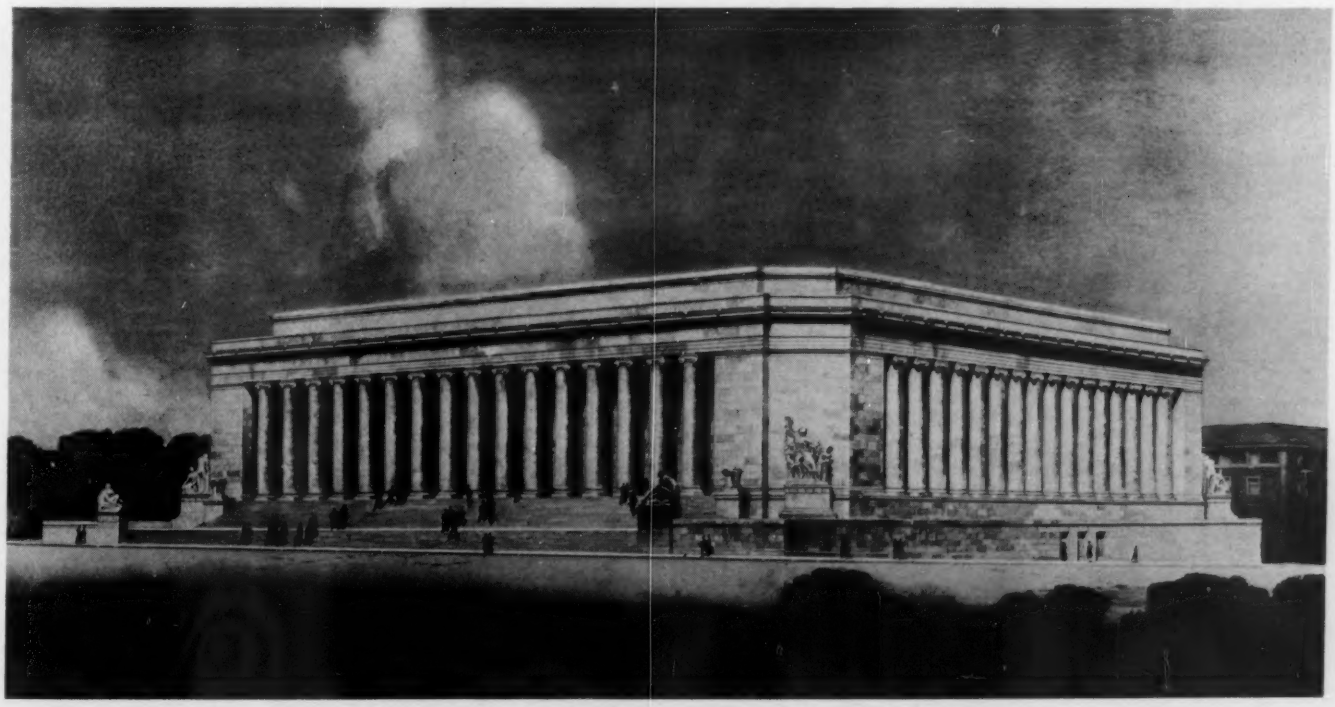
In the work accomplished to date, one might say that the surface has been merely scratched; there remains unlimited possibilities for development of the vast resources of this enormous country. Until the present, because of the difference between them, contacts between the United States and Russia have been hindered, but with the long-awaited recognition now an accomplished fact, the future holds great promise. Once more, credit should be freely given our administration which is primarily responsible for the opening of this great European country, the newest and greatest field of opportunity, to technical men.

BETRAYAL OF THE PUBLIC

THE advent of engineering in industry has made possible better products through designing and standardization, and more economical products through the introduction of mass production. However, it has failed in many instances to develop the best products. The engineer has been hampered by the capitalist who holds many of the new inventions in reserve until he has realized a profit on his present set up, or until he may play them as aces against his competitors. In this phase engineering is betraying the public. An example of this is the razor industry which has had on hand for more than a year a safety-razor blade with a nitrided edge which will maintain its keenness for months. Furthermore, a leading razor blade company has two men now working to develop a razor blade which can be used only once. The petroleum trust has long kept secret a process by which gasoline may be made more efficient.

Probably the worst offender is the motor car industry which has decorated its cars with "doodads" to take care of defects in previous models; but they make no attempt in many cases to strike at the root of the trouble with one device incorporating all these "brain children", for such a procedure would ostracize many of the "sales appeal" adjectives which fill out the advertisements and catch the eye of the gullible public. No manufacturer has put out the advocated streamlined car, for his business depends upon repetition, and, if he put out the ultimate now there would be no occasion to sell a new car later. An example of the delay which occurs in making inventions available to the public is the individual front wheel suspension which has been prevalent in Germany and other European countries for a number of years, and which was not scheduled to be introduced to the American market until this season.

These abuses are an outgrowth of the capitalist system, and should be overcome by specific regulation; whether this regulation comes in the form of limited time for patents subsidized by trusts, or by the establishment of a new economic order does not particularly matter. It remains that the hands of the engineer must be untied and his inventions made available if engineering is to serve the public fully and help raise the plane of living to the high position which it should hold.



The new Mellon Institute where science and industry will meet. *See page 144 for details.*

ENGINEERING DIGEST

SANDLESS SANDPAPER

THE fact that sandpaper contains no sand is surprising to most of the 60,000,000 people who use this important product. The fine abrasive particles on sandpaper are specially crushed flint or garnet or are products of the modern electric furnace—aluminum oxide or silicon carbide. Sand is not efficient for this purpose because the grains are usually rounded and have no sharp cutting edges.

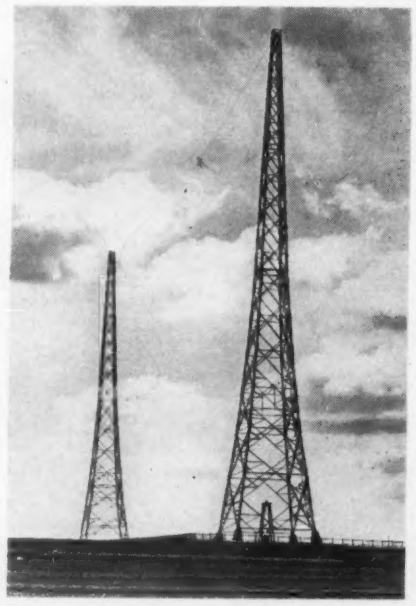
A problem that has faced engineers in this field has been to make as many as 35,000,000 tiny abrasive particles regiment themselves like so many soldiers, each with its sharpest cutting edge up, all evenly spaced, and all within one square inch. Its solution is the new "electro-coating" process which makes use of the electrostatic principal, first observed by Thales as long ago as 600 B. C.

The coating machine consists essentially of two flat, oblong electrodes, less than an inch apart, which are charged, the lower negatively and the upper positively, with a unidirectional potential of from 10,000 to 35,000 volts. Abrasive particles are fed onto an endless carrier belt which passes over the lower electrode. Freshly glued paper is passed over the upper electrode. The intense electrostatic field caused the particles to become charged and to stand on their long axes. The like charges on the particles cause them to repel each other and thus keep minutely separated, but at the same time they are repelled by the lower electrode and attracted by the upper electrode. Without breaking their formation they are violently propelled toward the upper electrode and imbed themselves in the freshly glued paper. The paper then leaves the coating machine and is dried in a separate chamber.

This process makes several major improvements in the field of coated abrasives. It spaces the abrasive evenly over the paper and makes sanding faster because the sharp edges and tips stand point up. It also gives the paper longer effective life because the particles are more securely imbedded. Replacement is lessened, thus minimizing costly delays of stoppage in mass and line production. (*Scientific American*, vol. 149, no. 5, November, 1933, pp. 216-217, 6 figs.) —J. D. M.

TIMBER RESEARCH

WIDER use of timber construction in this country by the introduction of metal connectors for strengthening timber joints was recently forecast in a report published by the Department of Commerce. Previous attempts to introduce metal connectors for wood joints into the United States proved unsuccessful because economic conditions were unfavorable. In Europe, however, the World War created such a demand for structural materials that steel became scarce and costly. This was particularly true among the Central Powers who were forced to find a substitute for metal structures and who carried out considerable research on timber joints.



Scientific American.

Radio towers, 330 feet high in Stuttgart, Germany, built with the aid of wood connectors.

The main disadvantage of wooden construction is the weakness of the joints. The adjacent timbers of a joint tend to slip past each other when they are under stress, pulling the bolt heads into the wood and bending the bolts at the same time. If a metal dowel or plate with teeth on both sides is placed between the adjacent faces of the members of the joint so that it is equally imbedded in each, the slipping tendency is taken care of almost entirely by the dowel or plate instead of the bolt. The connectors, instead of the bolts, transmit the load from one member to the other and the bolt is thus made a secondary load-bearing unit. Its main function is to prevent the members from spreading apart.

In general, there are three types of connectors. First there are plates which have teeth, spikes, or corrugations on the flat surfaces. By compressing the members of the joint after a connector is placed between them, the teeth of the connector are simultaneously forced into the faces of the members. In these, and in most other varieties of connectors, the bolt passes through a hole in the center of the connector. One variety of this type of connector was used in making a 460-foot radio tower at Breslau, Germany.

The second type of connector is a plain ring which fits into a precut groove, or a toothed ring which is forced into the members. Alligator connectors are examples of the latter variety and they were used in building Amundsen's dirigible hangar where he housed the "Norge" before his North Polar flight. Instead of a solid ring, split rings are often used because the bearing load is distributed over a greater area.

The third type of connector is the dowel which generally looks like two conic frustrums with their larger bases placed together. The 330-foot radio towers shown on this page were built with the aid of this sort of connector.

From actual tests it has been found that modern connectors have increased the safe working-load of joints by 200 to 400 per cent. This increased strength permits the use of weaker species of wood and smaller timbers, thereby cutting construction costs and giving the construction a more slender appearance. Another economy factor which is introduced by the use of modern connectors is the possibility of prefabrication of the construction. Labor costs can be materially reduced if the timbers are fitted and put together at the shop.

The number of uses which have been found for con-

nectors and timber construction in Europe is very extensive; hangars, railways sheds and terminals, grandstands, and radio towers are only a few instances of timber construction. The large number of uses for timber, coupled with the demand of engineers for a reduction in labor costs, will give a great impetus to its introduction into this country. (*Modern Connectors for Timber Construction*, a report published by the Department of Commerce in 1933)—P. W. A.

ABSOLUTE ZERO

WITHIN the last few weeks new low temperatures have been recorded by two important research groups. Previous efforts had been confined to the helium evaporation method with which Keesom produced 0.71° (Kelvin), representing the lowest limit of temperature obtainable by such methods.

A solution of the problem of still lower temperatures has been available to the unsuspecting scientist for many years. Workers in magnetism have long known of the magnetic-caloric effect, causing an adiabatic temperature gain by thrusting ferro-magnetic material into a strong magnetic field. This process changes the intrinsic magnetism of the micro-crystals of the substance, which causes a change of volume at the expense of internal temperature, resulting in an internal heat loss when no external heat is available. This phenomenon is strictly reversible and observable in any substance capable of magnetization.

Although realizing that any further approach to absolute zero had to be made by an entirely new method, it was only recently that scientists have utilized the caloric-magnetic effect for this work. Magnetic moment is roughly inversely proportional to the absolute temperature. Consequently magnetic-caloric effects are particularly pronounced at low temperatures and may be used to produce considerable adiabatic changes in temperature.

A strong magnetic field was maintained in the space occupied by a quantity of cerium fluoride cooled by the evaporation of liquid helium. On suddenly removing the magnetic field, the fluoride required heat energy to demagnetize the substance by destroying its large negative potential energy. This heat, coming from the substance itself, cooled the fluoride to below 0.27°K. Incidentally this cooling increased the magnetic moment and by testing the susceptibility of the substance to inductance the temperature was calculated, not by direct measurement, but by extrapolation from a susceptibility graph previously determined over a range of helium evaporation experiments.

Because adiabatic demagnetization has cooled substances from 3.4° K. to 0.53° K., from 2° to 0.34° and from 1.5° to 0.25°, it is evident that the new method will eventually permit of a still closer approach to absolute zero. (*Science Progress*, a quarterly, vol. 28, no. 110, October, 1933, pp. 279-281)—J. K. J.

DIMINUTIVE TUBES

TINY radio tubes, less than three-quarters of an inch in diameter, which operate excellently on wavelengths of less than one meter, are the latest development in ultra-short wave experimentation. These tubes are used in receivers and transmitters operating at frequencies of millions of cycles per second.

Conventional radio tubes operate fairly well at five meters, but below this wavelength the interelectrode capacities are so great that it is impractical to use them as oscillators. Under such conditions it is necessary to reduce tube and circuit dimensions in proportion to the wavelength.

Both the triode and the screengrid tubes have indirectly heated cathodes. A parallel plate structure is used, with cup anodes and flat disk grids. The leads are sealed into the bulb, thus reducing the lead inductance to a minimum. The inter-electrode spacings are in the order of 0.005 inches, necessitating great care in handling and mounting.

The triodes have oscillated at wavelengths as low as 30 cm. with very small plate voltages and currents. A receiver for 100 cm., using two stages of tuned radio-frequency amplification, a detector, and an audio amplifier operates well on signals from a single triode oscillator, modulated by a broadcast receiver. A two-tube receiver was used at 75 cm. with good results.

Considering the excellent performances of these tubes, it is to be expected that good superheterodyne receivers could be constructed for wavelengths approaching 50 cm. After suitable refinements of size, conventional tubes and circuits may be applied to the reception of these ultra-short waves.

It must be mentioned that these tubes are not available to the public, for they are not being manufactured on a production basis. Their use is purely experimental, in an interesting and perhaps important technical study. (*Electronics*, vol. 6, no. 3, August, 1933, pp. 214-215, 3 figs.)—J. D. M.

Electronics.

RESEARCH IN REVIEW

COURSE V — Chemistry

PROFESSOR NORRIS and the students working with him are continuing the study of the effect of the structure of molecules on the chemical reactivities of the atoms of which the molecules are composed. At present the methods developed are being applied to the chlorine atom in acyl chlorides and to the behavior of acids when concerted into esters.

The Raman spectra of certain acyl chlorides are being determined to discover if there is a relationship between the position of the lines produced by the carbon chloride bond and the reactivities of this bond as determined by chemical means.

The way in which aluminum chloride functions in certain examples of the Friedel-Crafts synthesis is being studied and the results are being utilized to develop new synthetic methods.

Tertiary butyl hypochlorite and tertiary butyl nitrite have been found to react readily with a large variety of organic compounds. The use of these substances is being studied in developing new methods for the preparation of important compounds. An improved method of making certain organic compounds. containing zinc has lead to a study of the wider application of these compounds in synthesis.

Electronics.

The neutron mill at the University of California. Keeping abreast of M.I.T. in research projects, the University of California is now carrying on investigations in connection with the structure of the atom.

Professor S. P. Mulliken with the cooperation of his colleagues and students in the Department of Organic Chemistry has been continuing the study of the systematic analytical characterization of organic compounds, a study begun in these laboratories over thirty years ago, and arrangements for a fuller utilization of the resulting material through publication as "Volume I" of an entirely rewritten "Second Edition" of "A Method for the Identification of Pure Organic Compounds" have just been completed, in which Professor Ernest H. Huntress will be the coauthor. Many of the new procedures are based on the results of recent experimental investigations by Reginald L. Wakeman, Gilbert C. Toone and others, which have not previously been made accessible through the current periodical literature. Beside presenting numerous contributions to the knowledge of its field, the present book is designed to serve as a practical laboratory manual for the use of students who are just beginning a general course in the study of organic qualitative analysis.

Professor Tenney L. Davis and some students are continuing a study of nitro—and nitroso—amines and urea derivatives in an effort to learn more concerning the manner in which various groups affect reactivity. They have recently succeeded in showing that the effect of alkyl groups in primary amines is strictly proportional to the effect of the same groups in primary alcohols. Another set of researches under Professor Davis' directions is devoted to the transformations of certain derivatives of metadiphenols, for the purpose of attaining a better understanding of the nature of quinones.

Professor Morton, with his students, is carrying out work on the structure of strychnine and brucine; on sodium condensations and the mechanism of the Wurtz reaction; and on the theory of the reaction of copper and other metals on benzoyl benzoate. In addition, they are examining certain polynuclear aromatic hydrocarbons in relation to the chemistry of cancer. *(To be continued in a future issue)*

COURSE I — Civil Engineering

IN the River Hydraulic Laboratory during the past year an extensive study was made of the transportation of sand by flowing water; investigations of the flow over a sharp-crested weir and of wave phenomena in a channel are still being carried on. Four thesis researches were housed in the laboratory: one was a study of spillway discharge variations with a varying angle of approach of the flow; a second dealt with the holding ability of various types of anchors; a third, still in progress, is a study of spillway design; the fourth, a doctor's thesis now under way, is an investigation of wave action at sea walls.

Research in Highway Transportation Economics is being conducted under the direction of Professor C. B. Breed to determine the annual road costs incurred in building and continuously maintaining highways of different types, and also to determine the extent to which these annual costs are defrayed in motor vehicle taxes by the vehicles using these roads.

HIGH-SPEED PHOTOGRAPHY

(*Continued from Page 131*)

sible to obtain pictures by *reflected* light instead of by *transmitted* light (shadow or silhouette photographs).

The requirements for a high-speed camera to be used with stroboscopic light are very simple when compared to the intermittent-motion type of camera. In general there are two main types of construction—the use of a drum which gives only a short length of film, and the use of a long continuous strip of film. The first type requires a shutter which is open for one revolution of the drum and which can be tripped at the critical moment to catch the picture. The second type does not require a shutter but does require a rapid acceleration so that only a small portion of the film will be wasted as it comes up to speed. A drum type of camera was built at the Institute in the aeronautics engine laboratory and successfully studied a diesel spray. For this work a stroboscopic mercury-arc lamp was put in the pressure cylinder into which the spray squirted. The pictures were taken the rate of two thousand a second.

A camera of the type using a long strip of film has been built in the Electrical Engineering Department and will now be described in some detail. In this camera the loaded film spool is placed at the top, on a shaft equipped with a small friction brake; the film is led over a drive sprocket about four inches in diameter then to a take-up spool at the bottom of the camera. A one-quarter horse-power induction motor operated at double voltage is belted to the main sprocket while another motor drives the take-up spool. The motor on the take-up reel is a series motor, which tends to run faster than required. It aids materially on the acceleration while the induction motor tends to hold constant the speed of the sprocket. Under these conditions the film attains a velocity of seventy-five feet per second in approximately one-quarter of a second and requires ten feet of film to reach full speed. A film speed of seventy-five feet per second corresponds to twelve hundred pictures a second when using thirty-five millimeter film or three thousand pictures a second when sixteen millimeter film is used. Pictures at a rate of six thousand a second have been taken by making the picture eight millimeters high. The commutator that controls the light is on the same shaft as the sprocket so that the light and the film are always synchronized. Timing is accomplished by means of a one thousand cycle spark which impresses a dot upon the edge of the film every thousandth of a second. Since the light from the mercury lamps is of good actinic value, it is possible in many cases to use positive motion picture film which has the advantage of fine grain. A photograph of the camera together with several illustrations of its uses are shown in the illustrations accompanying this article.

Cameras using flashing intermittent light such as the one just described are useless for problems which involve other strong light. The study of incandescent gases, the burning of materials, the timing of photo-flash lamps, the action of molten metal, and the like, are not in the range of its usefulness. For this work, however, the other type of cameras utilizing a moving optical system are particularly useful, especially since the light from such subjects is high, giving an exposure even with the necessarily short time of exposure.

A distinct advantage of the flashing light camera over the moving-optical-system type of camera is the shortness of exposure. This is of importance in some problems which involve the study of small objects going at high rates of speeds. Exposure time with the stroboscopic light varies from one millionth of a second to one hundred-thousandth of a second and thus is sufficiently short to prevent effectively any blurring because of motion of the object being photographed.

Both types of cameras require a certain amount of power for illumination, depending upon the type of subject, the speed of the camera, the area covered, and other factors. The stroboscopic type requires about ten kilowatts of power to cover an area one foot square at a speed of twelve hundred pictures a second. The entire equipment is portable but can be used only where there is a three-phase power supply capable of delivering this amount of power.

Important work is being done at the Institute to develop further the subject of high-speed photography. A few of the projects under way are: the development of a mercury-arc point source of light, the design of special reflectors to utilize more efficiently the light produced, the development of a special thyratron control tube for an open spark gap, increasing the frequency and efficiency of the light source, and the construction of a drum camera to take pictures at the rate of fifteen thousand a second.

The work of Professor Edgerton and Mr. Germeshausen has placed Technology in the forefront of the field of scientific motion study, the manifold possibilities of which are just beginning to be realized and understood.

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LIGHTSHIPS

(*Continued from page 135*)

propelled boat, fifty feet over-all, having a draft of two feet and nine inches.

The nature of their service—carrying supplies to light houses on isolated stations and to lightships—requires that they be strongly built with a high degree of seaworthiness. Also they must be designed with as low a draft as is consistent with stability, for in tending buoys they must work in and out among ledges and in close proximity to sandbars.

In general, tenders are designed according to the following lay-outs. The anchor windlass is forward on the main deck, generally protected by a forecastle head. Below are the crew's quarters. Then comes an open deck for the storage of buoys and anchors. The rails on both sides of this deck are easily removed to permit the lowering and raising of buoys. The forward mast is rigged as a derrick with a boom and falls to reach over the side. A large hatchway gives access to the forward hold where most of the freight is carried. Working aft, we find the officers' quarters, ward-room, galley, and upper entrances to the engine-room and bunkers. The stern is left open and contains two towing-bits. The gangways are usually enclosed affording greater protection in stormy weather. The upper or spar deck, runs from the forward mast to the stern. Here are the wheelhouse, captain's quarters, and state rooms for official passengers. The main-mast is used for displaying the service flag and as a support for the radio antenna. Practically all tenders on outside duty carry radio equipment at the present time.

The first tenders were sailing vessels. The first one of this class was the *Rush*, a revenue cutter transferred to the lighthouse service in 1840. The first steamer in the service was the *Shubrich* which went on duty on the Pacific Coast in 1858. She was a side wheeler. In 1865 the former *Iris* made her appearance as the first screw steamer to be used in this kind of work. Since then there have been constant additions until, according to recent reports, there were fifty-six tenders under the supervision of the lighthouse board.

Probably no other class of vessel is called upon to operate under such trying conditions of storms and sea. In fact so rigorous are their duties, in summer and winter, that it is necessary to build one or two new ones each year.

WEATHER FORECASTING

(*Continued from page 129*)

weather maps in the Meteorological Laboratory, and particularly in the preparation of the local weather forecast. In this latter connection these observations are especially useful in estimating the possibility of the development of local convective showers or snow flurries, and in estimating the amount of the diurnal temperature change during the following twenty-four hours. These are both phenomena which depend to a considerable extent upon the lapse rate, or vertical temperature distribution, in the atmosphere. But the real significance of the Technology station lies in the adaptability of the schedule of observations to meet the requirements of the special air mass and front structure investigations outlined above.

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ELECTROSTATIC GENERATOR

(*Continued from page 133*)

such that a flashover to ground will not occur until the potential of the unit has become greater than five million volts. The exterior of the column was impregnated with molten ceresine, which has a surface moisture resistance one hundred times better than that of any other material. The necessity of an excellent insulator which remains so even in damp weather is apparent when it is realized that the surface over which it is necessary to prevent leakage is about eight hundred square feet for each column. The resistance of the material is so great that only thirty micro-amperes of current are lost by leakage when the sphere is charged to three million volts.

Inside the column are the two paper belts which carry the charges to the sphere. (Only one belt was used when the photograph was taken in order that a clearer picture might be obtained.) These belts, which run at a tension of one thousand pounds, are four feet wide and only seventeen-thousandths of an inch thick. It has been estimated that their breaking load is about six thousand pounds. In actual use when the upper pulley jammed, the ten-horsepower motor stopped because of the load, but the belt did not fail. The insulating quality of the belt is good, and no difficulty has been experienced in its use, even though the belt runs at a speed greater than sixty miles an hour. One belt has been in use for a considerable period of time and has shown no appreciable wear. One of the outstanding points in favor of the use of the belt is that its cost is about one-fiftieth of that of ordinary materials, such as leather, rubber, or canvas.

In each column there is an air-conditioning apparatus, used to keep the humidity of the interior as near zero as possible. Silica gel is used to reduce the moisture content of the air. Electrical heaters slightly warm both the air and the columns so that no moist air condenses on the columns even though the air outside is saturated. Air conditioning of the inside insures warm dry air and reduces the leakage on the belts due to humidity.

In the base of the machine is located the driving power of the generator. An accompanying photograph shows the ten-horsepower motor behind the starting box, which is in the foreground at the right of the belt. Connecting the motor and the pulley used for driving the paper belt is a small leather belt. On the far side of the belt is located the device for "spraying" the charge on the "ascending" belt, known as a "corona wire." For starting the generator this wire, five mils in diameter and stretched one inch away from the belt, is charged to a potential of twenty-thousand volts from a kenotron rectifier set. The high potential gradient existing between the corona wire and the belt causes a large number of charges to migrate towards the belt where they are deposited and carried away.

Westinghouse.

A typically modernistic lamp designed for the World's Fair.

At the top a similar fine wire, but enclosed in and attached to a sheet metal shield (which is in effect a Faraday's "ice-pail"), is used to collect the charges just before they reach the upper pulley. A third corona wire is used to charge the "departing" belt to the opposite polarity as that of the "arriving" belt. This charge is in turn collected at the lower end of the belt in the same manner as at the top and may be used to cause the "spraying" of charges of the desired sign onto the "ascending" belt, thus completing the cycle. While the kenotron set is used to prime the generator, it is more convenient to operate the generator self-exciting after it is once operating. To do so, the charges of the undesired sign are used to maintain a potential of about the same value as that of the kenotron set and thereby pull the desired charges from the earth. When the generator is so self-excited, the only power required is that used to run the belt.

The power required to operate the belt is absorbed in two ways. About one-half is used to overcome

(*Continued on next page*)

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(*Continued from preceding page*)

windage losses and very small frictional losses in the bearings. The other half, which represents useful electrical power, is used in overcoming the electrostatic attractions between the charges. The ultimate efficiency is one hundred per cent. By enclosing a machine of this principle in a vacuum so as to eliminate windage effects, an efficiency very close to this maximum can be attained. The actual efficiency of the Round Hill generator is only fifty per cent, since little time has been spent in trying to make it more efficient. It can be expected that after a short period of experimentation the efficiency will equal or better that of the electromagnetic generator which has gone through a series of developments extending over a period greater than half a century. The outlook for the electrostatic generator is now very bright for it has not the disadvantage of copper and iron losses which exist in the familiar electromagnetic generator.

Those who understand electricity realize that it is impossible to measure the voltage of the generator by attaching a voltmeter between the two spheres. However, modern radio technique has made it quite easy to measure small electrical quantities. Since a voltage sets up an electrostatic field, it is possible to measure the voltage if the field can be measured. A revolving grounded shutter is employed to shield and expose alternately a terminal which is connected to a vacuum tube amplifier. The alternate exposure causes an alternating voltage which is proportional to the field strength and which when amplified by several vacuum tubes causes a deflection on an indicating meter. In this way the value of the electrostatic field is measured. Since the field existing is also proportional to the voltage on the huge sphere, the device can be calibrated from known voltages of small magnitude.

In breaking down the atom, one of the primary purposes for which the generator was built, modern vacuum technique is expected to be of great assistance. Its function here can be likened to that of the penstock which harnesses a mountain stream. The water running down over the rocks with its turmoil and spray makes a spectacular exhibit, but after all it is lost energy. To harness the water it is necessary to build a tube so that the water can flow freely without dashing against the rocks and losing its energy. And with the ten-million-volt generator it is necessary to build a great vacuum tube so that the electrons as they fall through a potential of millions of volts will not collide with air molecules and lose their energy. Since the particles will travel at speeds one hundred thousand times greater than those of the fastest rifle bullet, it is evident that the air resistance would be so great as to defeat the purpose of the experiment. The spectular twenty-foot flashes will be eliminated, for they are but waste power corresponding to the spray of the mountain stream. Modern vacuum technique, particularly through the very recent development of low vapor-pressure oils, makes it possible conveniently and effectively to get a high vacuum with diffusion pumps. In a vacuum with a pressure equal to one-billionth of an atmosphere, electrons will go zooming through space at a speed equal to ninety-nine per cent of that of light and bombard the atoms at the opposite end of a vacuum chamber.

The vacuum chamber, forty feet long, will be suspended between the two spherical terminals of the generator at a height of forty feet without any support other than that at the ends. Ordinary glass cannot be so used, since it is too fragile for convenience and lacks the mechanical strength necessary to span the gap; quartz, because of its expense, is out of the question; but here again textolite proves its value and is to be used.

Each sphere will contain a miniature laboratory. Lighting power will be supplied by a small electromagnetic generator receiving its driving power by a separate belt from below. For counting the fragments of the atoms as they are broken up by the electric bullets, extremely sensitive linear amplifiers will be used. Wilson Cloud Chambers, in which the paths of various particles can be photographed, will form an important part of the apparatus.

Nitroglycerine is ordinarily thought to be the most powerful substance. Calculations have shown that the volume concentration of energy in the nucleus of the atom is 10 000 000.000 000 000.000.000 (10^{22}) times as great as that liberated by nitroglycerine, which gets its power from the outer shell of the atom. Steam and electric power are feeble when compared to the atomic forces which *exist* whether or not man can harness them. That man will ever be able to harness these forces rests entirely upon how much the physicist can learn about the atom. That high-speed electrical particles shall prove to be an effective weapon is the hope of all those interested in the M. I. T. Round Hill generator.

THE NEW MELLON INSTITUTE

IN the midst of Pittsburgh's civic center, the new building of the Mellon Institute, the largest institution for industrial research in the United States, is approaching completion. The exterior, depicted on page 137, is practically finished, although it will require another year to equip fully the several hundred chemical, physical, and biological laboratories within.

Ionic architecture is used in the new seven-story structure, which is surrounded with high monolithic columns. It is 400 feet deep and extends, in front, 300 feet along Fifth Avenue. All the laboratories face courts in the interior of the building, and thus there are no windows on the outside.

The new laboratories will greatly expand the facilities of Mellon Institute and furnish more industrial concerns the opportunity to carry on research on its fellowship plan. More laboratories in pure chemistry and in chemical engineering will be available, in addition to rooms equipped for such special phases of technique as electrochemistry, spectroscopy, radiation measurement, and high-pressure experimentation. Other special features are a large lecture hall, a library to contain 250 000 volumes, a dining hall, a museum, and an underground garage.

By the Mellon Institute's plan of fellowships in industrial research, companies wishing solutions to their technological problems sponsor fellowships for which the Institute furnishes the laboratory facilities. Since there has been a long waiting list of companies that could not be accommodated for lack of rooms, the new building, donated by Andrew and R. B. Mellon, will fill a distinct need. —M.B.D.

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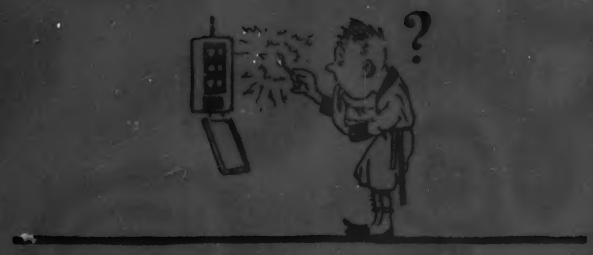

CENTLESS CIRCUITS

Conspicuous in nightmares of power company officials are ingenious, economical human beings who tinker with electric circuits, who rig up outlandish but convenient wiring. As a crowning touch to their handiwork, when fuses blow they use a penny. Lights go on. Protection goes out the cellar window.

To foil these handy-men-about-the-house, and to end blown-fuse troubles forever, G.E. has developed an ounce of protection — a little circuit breaker to replace the old-fashioned fuse box. It looks very much like an ordinary lighting wall-switch. When a "short" occurs, the arc is interrupted inside a small, closed, metal chamber in 0.008 of a second. A mere flip of the handle restores service.

Protection? The performance is so mild you can hear nothing and see nothing, even when 5000 amperes are being interrupted. And the breaker is safe and foolproof, too. The complete line will include ratings from 15 to 600 amperes. Let no more bridged-fuse bogeys disturb anyone's slumbers.

J. W. Seaman, Antioch College, '29, was very active in this development.

HATS OFF TO THIS ONE

The Sutorbilt Corporation of Los Angeles had a problem — to remove dried cocoanut meat (it's copra in the tropics) from a ship's hold to railroad cars at the rate of one ton every 60 seconds. That sounds like a lot of d.c.m. to most people — but it had to be done.

They built a machine with an 8-inch flexible metal throat and an amazing appetite. Not content with devouring copra, this machine gobbles up shiploads of potash, soda ash, borax, shale, grain, nuts — and even nibbles at the shirts, trousers, and hats of bystanders.

How? A G-E compensator starts a 150-hp. motor. An air compressor comes up to speed. Nature begins to "abhor a vacuum," and up comes everything but the bottom of the ship. If you have a cellar full of copra to be moved — or any similar problem — let us know.

STITCHING STEEL

Why not use vacuum tubes for speeding-up welders? So thought our engineers as they were working on the problem of stitching steel plates together with the rapidity of a sewing machine.

Thyratron-tube control for resistance seam welders resulted. H. W. Lord, '26 graduate of the California Institute of Technology, received a Charles A. Coffin Foundation Award* for developing an accurate timing circuit using Thyratron tubes — an important part of the control. Industry obtained a new high-speed production tool.

This control, when applied to line- or spot-welding machines, permits 1200 current interruptions per minute. Thus, it makes possible the stitching together of thin metal sheets to form gas-tight and water-tight seams. Thyratron-controlled machines will weld stainless steel, mild steel, chromium- and cadmium-plated steel, aluminum alloys, and many other materials. Steel barrels, pails, milk cans, and gasoline tanks are just a few of the many products now produced faster as a result of Thyratron welding control.

*A highly-prized company award, named after one of the founders of General Electric, that is awarded annually to selected employees for meritorious service.

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